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Abstract

This paper describes a novel approach proposed for use in the assessment of economywide costs of sectoral shutdowns introduced to curb the spread of Covid-19. Based on a supply-driven input-output (IO) model, our methodological framework allows for a decomposition of the total impact of sectoral shutdowns into i) losses in sectoral outputs resulting directly from the idling of factors of production employed in the sectors ordered to shut down, and indirectly from broken input-output linkages due to ii) interruption of the delivery of inputs from the sectors that have been shut down to others, and iii) suspension of input purchases by these sectors from others.

We demonstrate the use of proposed methodology to measure and decompose the effects of first round of shutdown orders that the Turkish government ordered for a number of service sectors over the period between March and June 2020 as part of the fight against the Covid-19 outbreak. We employ data from the most recent input-output table for Turkey, and carry out four simulation experiments. Our findings revealed that the upper bound for the cost of shutting down five sectors considered in the study could go as high as 7.2 percent of total gross output on an annual basis, exceeding 13 billion dollars in lost output and factor incomes.

Keywords: Input-output model, Covid-19, Sectoral shutdowns.
JEL Classifications: C67, I18, Z38.

I. Introduction

Governments everywhere are taking extraordinary measures to minimize deaths and to prevent national health systems from getting swamped by the flood of Covid-19 patients. Most of these measures are intended to control the spread of coronavirus (SARS-CoV-2) by restricting human mobility and contacts within and across communities, nationally and internationally.

Even though non-pharmaceutical measures like quarantines, curfews, lockdowns, shutdowns and other restrictions of similar nature serve to that purpose, they also limit i) consumers' ability and/or willingness to purchase and consume, and ii) producers' ability and/or willingness to produce and sell various commodities and services. The resulting drop in the final demand together with the simultaneous contraction of supply (and the associated decline in the demand for intermediate inputs) create severe economic costs, including huge output and employment losses in various sectors. Previously declared a pandemic by the WHO, Covid-19 outbreak has already caused a worldwide recession, producing economic effects that are comparable to (if not larger than) the effects of the global recession of 2008-2009, and the Great Depression of the 1930s in many countries.

In light of the trade-off between desirable public health outcomes and undesirable economic and social outcomes of measures taken to curb the spread of coronavirus, the biggest challenge before policy makers everywhere is to pick the right combination of measures to balance the public health concerns against employment and income considerations. While a complete shutdown of all productive activity not essential for human survival may stop the spread of the virus and minimize detrimental health effects, it will lead to massive unemployment and huge income losses, threatening the survival of not only businesses but also people whose livelihood is put at risk. At the other end of the spectrum, avoiding to impose any restrictions on economic activity could minimize immediate output and job losses but will eventually generate disastrous health effects –and second round supply effects. Most governments in the world have so far chosen measures and policies that will produce mixes of economic and health outcomes that are strictly between these two extremes. While the distance of the measures actually taken to either end of the spectrum varies across countries, a wide majority of governments have taken legally enforceable steps to largely or completely restrict supply-side activity in a number of sectors due to health risks.

Among the anti-pandemic measures taken in several countries were partial or (nearly) complete shutdowns of certain parts of the economy, particularly service sectors including tourism (accommodations and related) services, airlines and other modes of passenger transportation, dining, and entertainment services, for varying lengths of time. While such shutdowns were necessary for effectively curbing the spread of coronavirus disease, they created severe output and employment losses not only in the sectors directly receiving the shutdown orders but also in the rest of the economy, leading to further reductions in output and employment in sectors that sell/purchase inputs to/from sectors that have been shut down. Economic costs of such shutdowns vary across countries depending upon the relative shares of covered sectors in GDP, employment and foreign exchange receipts, as well as their connectedness to the rest of the economy, but are expected to be quite heavy for most countries.

Inspired by a previous study by Sayan and Demir (1998), we propose a novel methodology in this paper to measure the economywide costs of sectoral shutdowns introduced to control the spread of Covid-19 (and other epidemics), in terms of the resulting losses in sectoral outputs and the contraction of GDP by using a supply-driven input-output (IO) model. Such a systematic method of measuring output (and by implication, job) losses to result from sectoral shutdowns is imperative for informed decision making and is much needed by policy makers who are forced to seek the right balance between public health and economic costs of the pandemic.

We illustrate the use of the methodological framework we develop to measure and decompose the costs of anti-pandemic measures taken by Turkey, a country where a number of service sectors were completely shut down by the government first over the period between mid-March and June 2020, and then from late November 2020 to the present again as part of the fight against the Covid-19 outbreak. For this purpose, we use the most recent input-output data for Turkey, and carry out four simulation experiments using a *supply-side* input-output model of the Turkish economy. The experiment results allow not only for a measurement of the total cost of sectoral shutdowns, but also for a decomposition of total effects. Our findings point to sizable output losses

Methodologically, our analysis extends the demand-side version of the analytical framework first proposed by Carter (1965) and further developed by Sayan and Demir (1998) to the supply-side, along the lines first described in the latter study. While this demand-side approach was adopted also in other studies (see, for example, Guncavdi and Kucukciftci, 2002a and 2002b), the present study includes the first application of the supply-side version of this methodology after the original work by Sayan and Demir (1998). Our methodology is particularly useful for measuring and decomposing the sectoral and economywide effects of shutdowns that many countries introduced as part of their fight against the spread of Covid-19.

This paper contributes to the recently emerged "economics of Covid" literature. Relevant examples of this literature include Barrot, Grassi and Sauvagnat (2020), Barthélémy, et. al. (2020) and Navaretti et al. (2020). As for studies focussing specifically on the effects of Covid-19 on the Turkish economy, contributions that were particularly relevant to the present study came from Taymaz (2020); Cakmakli, et. al. (2020); Deger (2020) and Voyvoda and Yeldan (2020). Taymaz (2020) and Deger (2020) use demand-driven input-output models of the Turkish economy to explore possible effects of sectoral demand shocks associated with the pandemic. Taymaz (2020) models Covid restrictions imposed by the government on economic activity in a number of service sectors ranging from "Accommodation and food services" to "Transportation" as shocks leading to contractions in demand. Similarly, Deger (2020) investigates spill over effects of Covid-triggered drops in demand for the outputs of selected service sectors as revealed by data on credit card purchases. Cakmakli, et. al. (2020) study the macroeconomic effects of Covid-19 using a multisector-small open economy model which they calibrate to simulate the Turkish economy and capture the effects of Covid by feeding domestic infection rates into both sectoral supply and sectoral demand shocks. Finally, Voyvoda and Yeldan (2020) use a 24-sector CGE model of the Turkish economy calibrated to pre-Covid data, and investigate the effects of Covid-induced contractions in demand for the outputs of a similar set of service sectors as in Taymaz (2020).

The next two sections of the paper describe the methodological framework. Section IV reports results from the use of the proposed technique with the latest input-output data for the Turkish economy. Section V concludes the paper.

II. Basics of the Supply-Driven Input-Output Models

Two decades after the seminal work by Leontief (1936), Ghosh (1958) suggested a supply-side variant of Leontief's original, demand-driven input-output model, which could be solved using the same base year data as Leontief's model. Considering the case of *n* sectors or industries indexed over $i, j \in \{1, 2, \ldots, n\}$, and letting $\boldsymbol{Z} = [z_{ij}]$ be the *n*x*n* transactions matrix of interindustry sales by sector *i* to *all* sectors *j,* and $\boldsymbol{i}$ ' be the 1x*n* unit vector, the following identity holds by definition:

$$\boldsymbol{x} \equiv \boldsymbol{i}'\,\mathbf{Z} + \boldsymbol{v}' \tag{1}$$

for any vector of sectoral outputs $\boldsymbol{x}' = [x_1, x_2, \ldots, x_n]$, and the associated 1x*n* vector, $\boldsymbol{v}'$, of value-added (payments to primary factors of production) by each sector. In order to turn this (accounting) identity into an economywide equilibrium model, Ghosh (1958) let $\mathbf{B} = [b_{ij}]$ be the matrix of ratios of the values of inputs that sector *i* purchases from sector *j* to the value of sector *i*'s output in the base year: $b_{ij} = z_{ij} / x_i$. Since these shares of input purchases in the value of a sector's output remain reasonably stable over time, their values in a given base year can be taken to represent technological parameters characterizing a production function that (linearly) maps intermediate inputs delivered by sectors indexed over $j \in \{1, 2, \ldots, n\}$ to the sectoral output of sector *i*. One can then write

$$\boldsymbol{x}' = \boldsymbol{x}'\,\mathbf{B} + \boldsymbol{v}' \tag{2}$$

where $\mathbf{B} = \ddot{\boldsymbol{x}}^{-1}\,\mathbf{Z}$ with $\ddot{\boldsymbol{x}}^{-1} = \begin{bmatrix} 1/x_1 & 0 & \cdot\cdot & 0 \\ 0 & 1/x_2 & \cdot\cdot & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdot\cdot & 1/x_n \end{bmatrix}$.

Given the values of b_{ij}'s and sectoral value-added payments calculated from base year data, the vector that provides a solution to the set of unknown sectoral outputs can be found through

$$\boldsymbol{x}' = \boldsymbol{v}'(\mathbf{I} - \mathbf{B})^{-1} = \boldsymbol{v}'\mathbf{G} \tag{3}$$

as long as the determinant of $(\mathbf{I} - \mathbf{B})^{-1}$, or the so-called Ghosh inverse, $\mathbf{G}$, is different from 0. The solution (3) to the supply-side model will be the same as the solution obtained from the demand-side for the base year (Bon and Bing, 1993). Obviously, however, changes in sectoral outputs projected by the demand-side model in response to a change in final demands would not be the same as changes resulting from the supply-side model in response to a change in $\boldsymbol{v}$. The latter can be found from

$$\Delta\boldsymbol{x}' = \Delta\boldsymbol{v}'(\mathbf{I} - \mathbf{B})^{-1} = \Delta\boldsymbol{v}'\boldsymbol{G} \tag{4}$$

This equation can be used to quantitatively assess the effects on sectoral outputs of sudden changes in payments to primary factors of production (or sectoral magnitudes of value-added) in different sectors –due to shocks such as coronavirus-triggered shutdowns– by letting the relevant elements of $\Delta\boldsymbol{v}'$ corresponding to the affected sectors be different from 0 –accordingly with the contractionary or expansionary nature of value-added shocks.

In an input–output model, an exogenously induced change in the output of a particular sector, whether induced by a change in final demand for that product or in the availability of primary factors of production needed to produce it, has two kinds of effects on other sectors in the economy (Miller and Blair, 2009). First, a rise in sector *j*'s output will increase demand (from sector *j* as a purchaser) for inputs produced by other sectors. Secondly, such an increase in the output of sector *j* also implies that a higher supply (from sector *j* as a seller) of product *j* is available for delivery to other sectors that use it as an input in production.

Various methods have been proposed to assess a sector's capacity to prompt increased activity in the rest of the economy. A commonly used approach is to calculate the magnitudes of total backward and forward linkages for *each sector*, using the demand-driven and supply-driven input-output models, respectively (Miller and Blair, 2009). There is, in fact, a vast literature ranking the sectors in different countries in different periods of time, based on strengths of their backward and forward linkages as measured by different indicators. Such rankings serve as a tool to identify *key* or *leading* sectors in the economy, i.e., sectors with the largest capacity to generate activity in the rest of the economy. Knowing which sectors are more "important" in this sense is desirable for policy makers due to a large number of economic and social policy implications. At least as useful to know for policy making purposes is the degree of economic connectedness of a group of sectors together. Carter (1965) proposed a method allowing for an evaluation of the significance of a group of sectors together, using the demand-side model. Sayan and Demir (1998) not only extended Carter's demand-side methodology but also proposed a complementary methodology to measure the degree of interdependence between a cluster of sectors, that they called a bloc, with the rest, using the supply-side model as well. The bloc interdependence methodology proposed by Sayan and Demir (1998) is particularly useful to investigate the effects of shutdowns induced by Covid-19 (or other epidemics/pandemics). It allows for not just the measurement of the sum total of effects resulting from shutdowns but also for a decomposition of effects as described in the next section.

III. Bloc Interdependence in a Supply-Driven Input-Output Model

Sayan and Demir (1998) describe the need for analyzing bloc interdependence by noting that some exogenous shocks (such as Covid-19 epidemic) or policy changes (such as shutdowns) affect or target not just an individual sector but a group/cluster or bloc of sectors as a whole simultaneously.[3]

For such cases, a measure of bloc interdependence on the supply-side is obtained by partitioning the Ghosh inverse, or the **G** matrix, into submatrices and counterfactually setting the b_{ij} coefficients capturing the linkages among sectors in *different* blocs equal to zero. A comparison of the actual (i.e., observed) values of sectoral outputs to those resulting from the counterfactual assumption of a lack of input-output transactions across different blocs would show the strength of bloc interdependence. That is, when the deviations of counterfactual values of sectoral outputs from their actual values turn out to be sufficiently small (large) after the interaction terms across blocs have been set equal to 0, the bloc interdependence is considered to be weak (strong) (Sayan and Demir, 1998)

To facilitate a better understanding of the measurement process, let $\mathbf{B} = [b_{ij}]$ be the nxn matrix of supply-side input-output coefficients defined as $b_{ij} = z_{ij} / x_i$ as before. If k sectors ($k < n$) in the economy (or k of the n sectors in **B**) are marked to be shut down during the Covid-19 outbreak, these k sectors could be treated as a cluster or a bloc. Then, there will be another bloc made up of the remaining ($n - k$) sectors. Clustering all n sectors in **B** into two blocs called S (made up of sectors that are shut down), and O (containing other sectors), allows for a partitioning of **B** matrix into four submatrices as follows:

$$\mathbf{B} = \begin{bmatrix} B_{SS}^{kxk} & \vdots & B_{SO}^{kx(n-k)} \\ \cdots\cdots\cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ B_{OS}^{(n-k)xk} & \vdots & B_{OO}^{(n-k)x(n-k)} \end{bmatrix} \tag{5a}$$

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[3] Also, some structural transformation taking place over time may affect a certain bloc differently than others.

where B_{SS} and B_{OO} respectively are the kxk and $(n - k)\text{x}(n - k)$ submatrices containing the supply-side coefficients obtained from base year input-output transactions among the sectors *within* each bloc, whereas B_{SO} and B_{OS} are rectangular submatrices showing the supply-side coefficients obtained from base year input-output transactions across blocs (i.e., between sectors from different blocs). In other words, $B_{SS} = [{}^{SS}b_{ij}]\ \forall\ i, j \in \{1, 2,..., k\}$ and $B_{OO} = [{}^{OO}b_{ij}]\ \forall\ i, j \in \{k+1, k+2,..., n\}$ are diagonal submatrices capturing the within-bloc linkages among sectors marked to be and not to be shut down, respectively. Of the two off-diagonal submatrices, $B_{SO} = [{}^{SO}b_{ij}]\ \forall\ i \in \{1, 2,..., k\}$ and $j \in \{k+1, k+2,..., n\}$ contains input-output coefficients depicting deliveries of inputs from the sectors within bloc S to the remaining sectors (i.e., those in bloc O), while the elements of $B_{OS} = [{}^{OS}b_{ij}]\ \forall\ i \in \{k+1, k+2,..., n\}$ and $\forall\ j \in \{1, 2,..., k\}$ are coefficients representing purchases of inputs by the sectors within bloc S from those in bloc O.

By the same token, $(\mathbf{I} - \mathbf{B})$ can be written as

$$(\mathbf{I} - \mathbf{B}) = \begin{bmatrix} S_{SS}^{kxk} & \vdots & S_{SO}^{kx(n-k)} \\ \cdots\ \cdots\ \cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ S_{OS}^{(n-k)xk} & \vdots & S_{OO}^{(n-k)x(n-k)} \end{bmatrix} \tag{5b}$$

where S_{SS}, S_{SO}, S_{OS} and S_{OO} are submatrices obtained by subtracting the elements of corresponding submatrices in (5a) from the matching elements of the $n\text{x}n$ identity matrix. Thus, $(\mathbf{I} - \mathbf{B})$ in (5b) has $(1 - b_{ij})$ terms as the diagonal elements of diagonal submatrices S_{SS} and S_{OO}, and $-b_{ij}$'s elsewhere. Given (5b), it can be shown that the Ghosh inverse, $\mathbf{G}$, would be equivalent to the following partitioned matrix (Sayan and Demir, 1998):

$$\mathbf{G} \equiv (\mathbf{I} - \mathbf{B})^{-1} = \begin{bmatrix} (S_{SS} - S_{SO}\, S_{OO}^{-1} S_{OS})^{-1} & \vdots & -S_{SS}^{-1} S_{SO} \underline{S} \\ \cdots\ \cdots\ \cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ -\underline{S} S_{OS} S_{SS}^{-1} & \vdots & \underline{S} \end{bmatrix}. \tag{5c}$$

where $\underline{S} = (S_{OO} - S_{OS}\, S_{SS}^{-1}\, S_{SO})^{-1}$.

Suspension of production activity in certain sectors during a coronavirus-induced shutdown would obviously disrupt intersectoral input-output flows in the economy. A shutdown, in fact, creates two types effects on these flows. First, the shutdown would interrupt deliveries of inputs *from* sectors that have been shut down *to* others. Secondly, sectors covered by the shutdown (bloc S) would no longer be able to ship inputs *to* other sectors (bloc *O*). The methodology developed by Sayan and Demir (1998) allows for a calculation of these effects separately.

The first type of effects can be captured first by counterfactually setting all elements of S_{SO} equal to 0.[4] This will yield the following modified version of the Ghosh inverse, $\mathbf{G}|_{SO=0}$:

$$\mathbf{G}|_{SO=0} = \begin{bmatrix} S_{SS}^{-1} & \vdots & 0 \\ \cdots\ \cdots\ \cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ -S_{OO}^{-1}S_{OS}S_{SS}^{-1} & \vdots & S_{OO}^{-1} \end{bmatrix}. \qquad (6a.1)$$

Equation (4b) can then be used to assess these effects. Sectoral outputs to be produced after input purchases of S-bloc sectors from O-bloc have been suppressed will be given by:

$$\boldsymbol{x}'|_{SO=0} = \boldsymbol{v}'\,\mathbf{G}|_{SO=0} \qquad (6a.2)$$

This vector of outputs can now be compared to sectoral outputs actually observed in the base year, i.e., in the absence of the shutdown. Percentage change in sectoral outputs resulting from this component of the pandemic shock can be computed by dividing each element of the vector of differences $\Delta\boldsymbol{x}'|_{SO=0}$ by the corresponding element of the original (i.e., base year) output vector $\boldsymbol{x}'$. Here,

$$\Delta\boldsymbol{x}'|_{SO=0} \equiv (\boldsymbol{x}'|_{SO=0} - \boldsymbol{x}') = \boldsymbol{v}'\,\mathbf{G}|_{SO=0} - \boldsymbol{v}'\,\mathbf{G} = \boldsymbol{v}'\,(\mathbf{G}|_{SO=0} - \mathbf{G}) \qquad (6a.3)$$

The second type of effects results from the termination of deliveries of inputs needed by sectors in *S* from others during the shutdown. This interruption can be simulated by counterfactually muting the channel by which *O*-bloc sectors supply inputs to the sections of the economy that have been shut down,[5] such that the modified version of the Ghosh inverse, $\mathbf{G}|_{OS=0}$ will be given by:

$$\mathbf{G}|_{OS=0} = \begin{bmatrix} {S_{SS}}^{-1} & \vdots & -S_{SS}^{-1}S_{SO}\underline{S} \\ \cdots\ \cdots\ \cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ 0 & \vdots & {S_{OO}}^{-1} \end{bmatrix}. \qquad (6b.1)$$

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[4] It can be shown that this is equivalent to counterfactually setting ${}^{SO}b_{ij} = 0 \; \forall \; i \in \{1, 2,..., k\}$ and $j \in \{k+1, k+2,..., n\}$ so as to turn B_{SO} into a matrix with 0's everywhere.

[5] Once again, it can be shown that this is equivalent to counterfactually setting ${}^{OS}b_{ij} = 0 \; \forall \; i \in \{k+1, k+2,..., n\}$ and $j \in \{1, 2,..., k\}$ so as to convert B_{OS} into a matrix with 0's everywhere.

Again, the magnitude of this second type of effect can be found by subtracting initial values of sectoral outputs from the vector of outputs obtained after replacing the original Ghosh inverse with $\mathbf{G}|_{\mathrm{OS=0}}$:

$$\boldsymbol{x}'|_{\mathrm{OS=0}} = \boldsymbol{v}'\,\mathbf{G}|_{\mathrm{SO=0}} \qquad (6b.2)$$

Calculation of total cost of the disruption of input-output flows due to the shutdown requires combining sectoral output losses resulting from the silencing of connections between *S* and *O* blocs in both directions. This can be achieved by calculating sectoral outputs from equation (4b) after replacing the **G** matrix in (5c) with the following:

$$\mathbf{G}|_{\mathrm{OS=0\ and\ SO=0}} = \begin{bmatrix} S_{SS}{}^{-1} & \vdots & 0 \\ \cdots\ \cdots\ \cdots & \vdots & \cdots\cdots\cdots\cdots\cdots \\ 0 & \vdots & S_{OO}{}^{-1} \end{bmatrix}. \qquad (6c.1)$$

where $\mathbf{G}|_{\mathrm{OS=0\ and\ SO=0}}$ is the Ghosh inverse in (5c) with $\mathbf{G}|_{\mathrm{SO=0}}$ inserted to replace its upper-left corner, and $\mathbf{G}|_{\mathrm{OS=0}}$ inserted to replace its lower-right corner. Thus, total effects on sectoral outputs coming from the shutdown-order-induced interruption of the deliveries of inputs from (to) the *S*-bloc to (from) the *O*-bloc sectors will be given by:

$$\boldsymbol{x}'|_{\mathrm{OS=0\ and\ SO=0}} - \boldsymbol{x}' = \boldsymbol{v}'\,(\mathbf{G}|_{\mathrm{OS=0\ and\ SO=0}} - \mathbf{G}) \qquad (6c.2)$$

Obviously, costs of shutting down certain sectors to slow down the spread of Covid-19 are not limited to losses resulting from the discontinuation of input-output transactions between shut down sectors and the others. They also include the drop in the value-added (i.e., the wage receipts and capital earnings going to factors production employed) in the covered sectors. In other words, a complete shutdown implies that the owners of the primary factors of production employed in the covered sectors will not be compensated for their productive services over the shutdown period.[6] Thus, the first *k* elements corresponding to the sectors in bloc *S* in the original (or base year) value-added vector $\boldsymbol{v}' = [v_1 , v_2 , v_3 , \ldots, v_k , v_{k+1} , \ldots, v_n]$ should be replaced with 0's after the shutdown yielding $\boldsymbol{v}_s' = [0 , 0 , 0 , \ldots, v_k , v_{k+1} , \ldots, v_n]$ as the post-shutdown value-added vector.

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[6] We do not consider the possibility of a continuation of payments to primary factors of production during the shutdown due to the imposition of a firing ban, union power, unemployment insurance and other government operated schemes etc. So, the counterfactual scenario we consider may be taken to represent the upper bound for the magnitude of effects spreading across sectors through input-output linkages.

One can now find the effects of the elimination of value-added payments due to the cessation of production in the shut down sectors upon all sectoral outputs by using equation (4c). Defining the $\Delta \boldsymbol{v}'$ term in equation (4c) as the difference between the post-shutdown value-added vector $\boldsymbol{v}_{\mathrm{S}}'$ and the initial value-added vector $\boldsymbol{v}'$, the resulting difference vector $\Delta \boldsymbol{v}_{\mathrm{S}}'$ will be $\Delta \boldsymbol{v}_{\mathrm{S}}' = \boldsymbol{v}_{\mathrm{S}}' - \boldsymbol{v}' = [- v_1 , - v_2 , - v_3 , \ldots, - v_k , 0 , 0 , 0 , \ldots, 0]$. Substituting this and the original Ghosh inverse in equation (4c) yields

$$\Delta \boldsymbol{x}' = \Delta \boldsymbol{v}_{\mathrm{S}}' \, \mathbf{G} \tag{7}$$

which can be expressed in *percentage* terms by the product $\Delta \boldsymbol{x}' \ddot{\boldsymbol{x}}^{-1}$ as before.

IV. Simulation Experiments and Numerical Results

In this section, we illustrate the use of the methodology we described in measuring the economic costs of recent shutdown orders covering a number of different sectors in the Turkish economy against Covid-19. For this purpose, we use information from 2012 on input-output transactions between 64 different sectors of the Turkish economy published by TurkStat. This is the latest available input-output data and has also been used for recent assessments of the effects of Covid-19 by Taymaz (2020) and Deger (2020) who focused solely on the demand-side effects of the pandemic and hence, used a demand-side input-output model of the Turkish economy.

Our model has 64 sectors (see Appendix for a full list of sectors). The sectors that have been shut down as ordered by the government as a measure against the spread of the pandemic (and their *CPA 2008 Codes*) are: i) Accommodation and food services (*I*), ii) Travel agency, tour operator and other reservation and related services (*N79*), iii) Creative arts; Entertainment; Library, archive, museum, and other cultural services; Gambling and betting services (*R90-R92*), iv) Sporting services, and Amusement and recreation services (*R93*), v) Other personal services (*S96*).[7] These sectors together accounted for 4.84 percent of total factor income generated (GDP at factor cost), and roughly 4.27 percent of GDP at market prices in 2012.[8]

We first create a 64x64 matrix $\mathbf{B} = [b_{ij}]$ of supply-side input-output coefficients from the 64x64 transactions matrix of interindustry (or intermediate input) sales, $\mathbf{Z} = [z_{ij}]$, and run a consistency

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[7] Services of airlines and intercity passenger buses have also been suspended for a while but the sectoral classification in the Turkish input-output table does not allow for distinguishing passenger transportation from cargo transportation in the "Air transportation" sector (*H51*), and from cargo transportation and pipelines in the case of "Land transportation" sector (*H49*). We thus only considered only those sectors shut down almost completely from mid-March to early June.

[8] GDP at market prices is equal to total factor income plus indirect taxes (net of subsidies) on products.

check by solving equation (4a). The data for the 1xn value-added vector $\boldsymbol{v}$ ' come from the original transactions matrix and include payments to labor and capital, as well as imports, for each sector. After making sure that the base year solution vector of sectoral outputs $\boldsymbol{x}' = [x_1, x_2, \ldots, x_n]$ from equation (4a) reproduces sectoral output in the base year data, we run four simulation experiments to observe and decompose total, economywide costs of shutdowns in the relevant sectors into output effects resulting from the interruption of these sectors' sales of inputs to and purchases of inputs from other sectors, and value added effects.

The experiments are described below:

1- In the first experiment, we look at economywide losses in sectoral outputs resulting from the disruption of deliveries *from* the shut down sectors *to* the other sectors that need inputs. In other words, this experiment simulates the scenario where deliveries of inputs to other sectors are discontinued due to the suspension of production in the sectors receiving the shutdown orders. Mathematically speaking, the experiment amounts to comparing $\boldsymbol{x}'|_{SO=0}$ –the post-shutdown vector of sectoral outputs found from equation (6a.2) by muting the intersectoral flows of inputs from S-bloc to O-bloc– to $\boldsymbol{x}$ ', the vector of initial (pre-pandemic) outputs.

2- In the second experiment, sectoral output losses result from the plummeting to the ground of input purchase orders placed *by* the sectors that have been shut down. Thus, this experiment focuses on the effects of termination of input shipments *from* other sectors *to* the sectors where production activity is suspended due to the shutdown. The resulting effects from the disturbance of input-output flows through this second channel are captured by calculating sectoral output losses from equation (6b.2).

3- The third experiment combines the first two scenarios to find out the total impact of the shutdown coming from each broken channel of connections between S and O blocs due to the shutdown together. In mathematical terms, this experiment amounts to finding sectoral output losses from equation (6c.2).

4- The final experiment realistically considers sectoral shutdowns as policies that lead not only to a disruption of *all* input-output transactions between the sectors that are shut down and the rest of the economy (i.e., interruption of input-output flows in both directions), but also to a disruption of payments to labor, capital and to the rest of the world in the affected sectors. In this experiment, we halt receipts of wages by workers, and rents, profits and interest earnings by the owners of capital installed in the covered sectors, as well as sales receipts of foreign companies that supply imports, as a complete shutdown would require. In mathematical terms, this experiment is equivalent to finding $\Delta\boldsymbol{x}$ ' from equation (7).

Numerical results we obtained using the 2012 input-output transactions table for the Turkish economy (the latest available) are presented in Tables 1 and 2.

Table 1. Decomposition of the Effects of Shutdown on Sectoral Outputs by Experiments: *S*-bloc Sectors (%)

Sectoral CPA Code	Activity Descriptions of Sectors Shut Down	Base Share in Gross Output / Factor Income	Deviations of Sectoral Outputs from Actual Base Year Values under			
			Exp. 1	*Exp. 2*	*Exp. 3*	*Exp. 4*
I	Accommodation and food services	2.54 / 3.09	-0.28	-46.86	-46.89	-53.29
N79	Travel agency, Tour operator and other reservation services, and related services	0.55 / 0.40	-0.58	-47.69	-47.97	-52.61
R90-92	Creative arts; Entertainment; Library, archive, museum, and other cultural services; Gambling and betting services	0.41 / 0. 69	-0.34	-21.44	-21.51	-78.74
R93	Sporting services, and Amusement and recreation services	0.26 / 0.27	-0.43	-53.29	-53.52	-46.94
S96	Other personal services	0.37 / 0.39	-0.46	-55.92	-56.18	-44.32

Combined share of the five sectors that were instructed to terminate productive activity in order to curb the spread of Covid-19, together stood at 4.13 percent of the total value of the gross outputs of all sectors, and 4.84 percent of total payments to factors of production in the base year. Simulation results reported in the table decompose the effects of this termination of productive activity on the shut down sectors themselves. For three of these sectors (I, N79 and R90-R92), the effect causing the largest contraction in sectoral outputs is coming from discontinuation of factor payments, whereas for the remaining two (R93 and S96), it arises from the inability to purchase (and use) inputs produced by other sectors. For all five sectors, by far the smallest effects on sectoral outputs are inflicted by their post-shutdown failure to deliver inputs needed by other sectors. This is in line with expectations, since services supplied by sectors that were shut down typically serve to final rather than intermediate input demand by companies in other sectors.

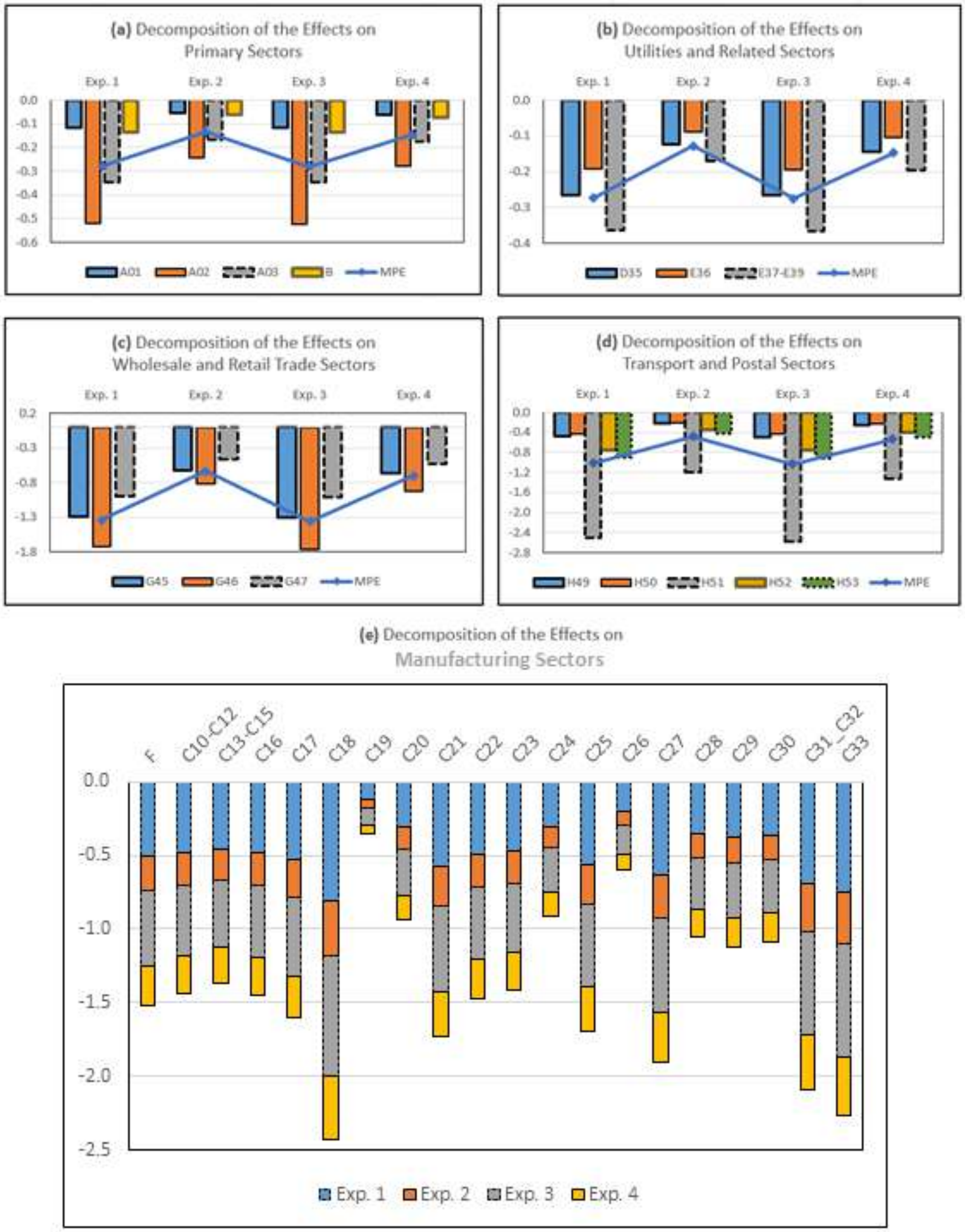
Table 2 and Figure 1 show decomposition of the effects that the shutdown inflicts upon the other sectors under each experiment scenario. The numbers reported in the table are mean percentage errors (MPEs) calculated for groups of sectors from the deviations of individual sectors' gross outputs from actual base year values under each experiment. Perhaps the most striking result is the relatively larger size of output effects on service sectors in all four experiments, as compared to sectors producing primary and manufactured goods, as well as utilities and construction. To be more precise, sectors whose shares in total factor incomes exceed their shares in total gross output (as indicated by the numbers in the third column of Table 2) get affected visibly more than sectors whose shares in total factor incomes are lower than their respective shares in total gross output. Most service sectors fall into the first category, while almost all manufacturing sectors and construction fall into the latter category. Given that many of the service sectors in the first group have also experienced significant contractions in demand in the aftermath of Covid-19 outbreak, it would be appropriate to view the pandemic as a shock primarily hitting service sectors whether they have received the shutdown orders or not.

Table 2. Decomposition of the Effects of Shutdown on Sectoral Outputs by Experiments: Mean Percentage Errors (MPE) for Sector Groups in *O*-bloc (%)

Sectoral CPA Code	**Activity Descriptions of Sectors**	**Share in Gross Output / Factor Income**	**Deviations of Sectoral Outputs from Actual Base Year Values under**			
			Exp. 1	***Exp. 2***	***Exp. 3***	***Exp. 4***
A01-A03, and B	Primary goods (Agriculture; Forestry; Fisheries; Mining and quarrying)	8.96 / 9.63	-0.280	-0.133	-0.281	-0.147
C10-C33, and F	Manufacturing, and Construction	44. 84 / 26.33	-0.473	-0.221	-0.475	-0.252
D35, and E36-E39	Utilities and related products; Sewerage and Waste disposal	5.02 / 2.79	-0.275	-0.128	-0.275	-0.147
G45-G47	Wholesale and retail trade	8.51 / 12.55	-1.342	-0.638	-1.361	-0.706
H49-H53	Transportation and support services for transportation; Postal and courier services	7.84 / 9.34	-1.016	-0.479	-1.033	-0.539
J58-J63	Publishing services; Broadcasting; Telecom and computer support services	2.10 / 3.00	-2.395	-0.964	-2.510	-1.436
K64-K66, and L68B	Financial services; Insurance and related services; Legal and managerial services; Real estate services	7.41 / 13.41	-1.001	-0.464	-1.014	-0.538
M69-M75, and S95	Technical and scientific services	2.40 / 3.47	-1.746	-0.819	-1.798	-0.930
N77-N78, N80-N82, 084, P85, Q86-Q88, S94, and T	Other services	8.76 / 14.59	-1.473	-0.697	-1.506	-0.778
MPEs for all sectors with output share < share in factor receipts			-1.070	-0.505	-1.087	-0.567
MPEs for all sectors with output share > share in factor receipts			-0.885	-0.388	-0.914	-0.498
Total economywide *loss* in gross outputs (%)			0.628	2.173	2.501	4.748

The last row in Table 2 indicates that total cost of shutting down the five sectors due to the pandemic may exceed 7.2 percent of total gross output when we consider the output losses resulting from disruption of input-output flows in both directions (about 2.5 percent) together with the drop in total factor incomes in the shutdown sectors (about 4.7 percent).

Figure 1. Decomposition of the Effects of Shutdown on Manufacturing and Construction Sectors



Naturally, these numbers point to *annual* losses, and they must be discounted accordingly with actual duration of any shutdowns lasting shorter than a year. It could be argued, therefore, that the almost complete shutdown of these sectors alone for nearly 3 months must have led to a loss of about 1.8

percent of the total gross output in the Turkish economy. Given the current size of the Turkish economy, this translates to more than 13 billion dollars, a huge amount even by overlooking the effects of tourism revenues on current account, foreign exchange reserves etc.

V. Concluding Remarks

Many countries around the world have introduced legally enforceable measures to partially or completely restrict productive activity in certain sectors so as to curb the spread of Covid-19 epidemic. Anti-pandemic measures were particularly severe in a number of service sectors such as tourism (accommodations and related) services, airlines and other modes of passenger transportation, dining, and entertainment services, and often included large scale or even complete shutdowns. The shutdown orders issued by governments not only stopped productive activity in the covered sectors but also caused severe contractions in output and employment in sectors that sell/purchase inputs to/from sectors that have been shut down. While varying across countries depending upon the relative shares of covered sectors in GDP, employment and foreign exchange receipts, and the degree of their connectedness to the rest of the economy, economic costs of such shutdowns are expected to be quite heavy for most countries. Well-designed approaches for systematic measurement of possible output and job losses to result from sectoral shutdowns are much needed for informed decision making by policy makers who are burdened by the tough task of striking a balance between public health and economic costs of the pandemic.

This paper proposed a novel methodology that can be used to assess economic costs of sectoral shutdowns going into effect against the spread of Covid-19 (and other epidemics and similar shocks such as natural disasters), in terms of the losses in sectoral outputs and the contraction of GDP by using a supply-driven input-output model. Our framework allowed for a decomposition of the effects of sectoral shutdowns into direct and indirect losses resulting from the interruption of factor payments to the owners of factors of production employed in the sectors ordered to shut down, and from the broken input-output linkages due to i) suspension of the delivery of inputs to sectors that are allowed to continue productive activities, ii) termination of the demand for inputs produced by sectors shut down.

We illustrated the use of this methodological framework in the measurement and decomposition of the effects observed in Turkey, a country where a number of service sectors were completely shut down by the government for a while, as part of the fight against the Covid-19 outbreak. For this purpose, we used the most recent input-output data for Turkey, and carried out four simulation experiments. Our findings revealed that the upper bound for the cost of shutting down five sectors considered in the study could go as high as 7.2 percent of total gross output on an annual basis, exceeding 13 billion dollars in lost output and factor incomes. While huge, these costs of shutdowns must obviously be weighed against public health costs associated with continuation of unrestricted productive activity in the sectors that pose higher health risks. In fact, the apparent surge in these health costs forced the Turkish government to shut down all in-room dining services offered by restaurants, cafes etc. starting November 2020 again, despite severe output, employment and income costs to the economy. The magnitude of costs from this second round of shutdowns remains to be seen, as these are still in effect.

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Appendix

Sector Coverage of the Input-Output Model by CPA Codes

I	Accommodation and food services
N79	Travel agency, Tour operator and other reservation services, and related services
R90-R92	Creative arts; Entertainment; Library, archive, museum, and other cultural services; Gambling and betting services
R93	Sporting services, and Amusement and recreation services
S96	Other personal services
T	Household services (provided by hired helpers); Undifferentiated goods and services produced by households for own use
A01	Agriculture; Hunting, and related services
A02	Forestry products, logging and related services
A03	Fish and other fishing products; Aquaculture products; Support services to fishing
F	Construction and construction works
C10-C12	Food, beverages and tobacco products
C13-C15	Textiles, wearing apparel, leather and related products
C16	Wood; Wood and cork products (exc. Furniture); Articles made of straw and other plaiting materials
C17	Paper and paper products
C18	Printing and recording services
C19	Coke and refined petroleum products
C20	Chemicals and chemical products
C21	Basic pharmaceutical products and pharmaceutical preparations
C22	Rubber and plastic products
C23	Other non-metallic mineral products
C24	Basic metals
C25	Fabricated metal products (exc. Machinery and equipment)
C26	Computers, electronic and optical products
C27	Electrical equipment
C28	Machinery and equipment n.e.c.
C29	Motor vehicles, trailers and semi-trailers
C30	Other transportation equipment
C31_C32	Furniture and related manufactured goods
C33	Machinery and equipment repair and installation services
D35	Electricity, gas, steam and air conditioning
E36	Natural water; water treatment and supply services
E37-E39	Sewerage services; Sewage sludge; Waste collection, treatment and disposal services; Materials recovery services; Remediation services and other waste related services
G45	Wholesale and retail trade and repair services of motor vehicles and motorcycles
G46	Wholesale trade services (exc. Motor vehicles and motorcycles)
G47	Retail trade services (exc. Motor vehicles and motorcycles)
H49	Land transport services and transport services via pipelines
H50	Water transport services
H51	Air transport services
H52	Warehousing and support services for transportation
H53	Postal and courier services
J58	Publishing services
J59_J60	Motion picture, video and TV programme production services; Sound recording and music publishing; Programming and broadcasting services
J61	Telecommunications services
J62_J63	Computer programming, consultancy and related services; Information services
K64	Financial services (exc. Insurance and Personal pension accounts)
K65	Insurance, reinsurance and personal pension account services (exc. Compulsory social security)
K66	Services auxiliary to financial services and insurance services

L68B	Real estate services (excluding imputed rents)
M69_M70	Legal and accounting services; Managerial services and Management consulting services
M71	Architectural and engineering services; Technical testing and analysis services
M72	Scientific research and development services
M73	Advertising and market research services
M74_M75	Other professional, scientific and technical services, and Veterinary services
S95	Repair services of computers and personal and household goods
N77	Rental and leasing services
N78	Employment and recruitment services
N80-N82	Security and investigation services; Building maintenance and landscape services; Office administrative, office support and other business support services
P85	Education services
Q86	Human health services
Q87_Q88	In-house care services; Social work services without accommodation
S94	Membership-based services